Getting Started in Visualization

by
Julian Gallop
Rutherford Appleton Laboratory
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Introduction

It has been difficult to pick up a scientific or computing joumal in the last few years, without seeing an article about "scientific visualization" or "Visualization in Scientific Computing" or (still in a scientific context) simply "visualization". From these one might gain the impression that: visualization can produce stunning pictures; it needs powerful computers; all the contact addresses are in the USA; visualization can help to solve earth shattering problems, but is unsuitable for my own research.

A number of books describe the current state of the art. [Friedhoff91], [Brodlie92] and [Earnshaw 92] are good examples and each has a distinctive contribution. All repay further study.

What has not been available is a handy publication:

- which describes the practical solutions available to a scientific or engineering investigator, a user of this new technology, and provides information iritended to help make an informed choice;
- for which the publication process is not lengthy, so that the information is closer to being up to date when it appears and revising it is not prohibitive;
- which is written from the perspective of the UK academic community.

The Visualization Community Club of the UK Science and Engineering Research Council saw this deficiency and recommended that such a publication be produced - this booklet being the result. Useful information has also been provided by the Visualization Support Officer for the UK Advisory Group on Computer Graphics (Steve Larkin of the University of Manchester).

The information in this booklet will be updated 2-3 times a year and so the opportunity to make improvements exists. Keeping the information up to date will rely on readers noticing. If you can suggest improvements or provide updated information, please communicate this to:

Julian Gallop Visualization Group, Informatics Dcpartment, Rutherford Appleton Laboratory Chilton Didcot OX I I OQX UK e'mail: *jrg@inf.rl.ac.uk*

This document will also be kept online.

For those who care about the spelling ... visualisation or visualization

Much debate appears to take place, whether 's' or 'z' should be used: visualise or visualize. Common usage of this word in the UK (outside the computing context) favours 's' and there is a danger of setting up false distinctions in the reader's mind - using 'z' for the technology, and 's' for the human activity. However the Oxford English Dictionary - not noted for being American uses 'z', with 's' as an allowed alternative, and therefore the 'z' spelling will be used here. Whatever the spelling, the technology is intended to assist, broaden and stimulate the human investigator to visualize the phenomena under investigation more deeply.

1. If visualization is the solution, what is the problem?

Present day scientific and engineering investigators are confronted with research problems that depend on gaining insight into complex and voluminous data. Previous publications - particularly [McCormick 871 - have referred to

- *firehoses* of data, powerful computers and automatic experiments, which produce data at a greater rate than the mind can comprehend, resulting in
- *warehouses* of data where much is left untouched, hiding unsuspected insights.

Scientific visualization is devoted to providing visual tools and methods (and some non-visual ones) to help a scientific or engineering investigator with analysing data.

Characterising the investigator's problem

There is no single visualization method or tool that can be applied successfully to all problems of data analysis. Therefore if visualization is intended to assist with demanding problems, it is worthwhile beginning by characterising in what way the investigator's problem is demanding:

- *Multidimensional* - at the extremes there may be 1 or many independent variables. A common example is 3 where the independent variables are spatial dimensions or 2 where the third dimension can be ignored. Often in the past, the 3rd dimension has been ignored not only because the computation has been difficult. but because displaying the result has also been difficult.

- *Multivariate* - there may be 1 or many dependent variables. Much hype from product brochures blurs the distinction between the independent and dependent variables, resulting in confusing claims such as "This system handles 4D data".

- *Compound data* - data could exist as a number of scalars at each sampled point. However many problems respond better if the internal structure of the data is respected. Thus data about flow and gradients can be represented as vectors. Data aboul strain can be represented as tensors. Electrical data can be represented as complex numbers.

- *Geometry* - some systems assume that a Cartesian coordinate space is being used. Many problems are defined on a curved space. Some data can be defined on parameters such as (u,v) or (phi,theta), which are themselves used to define a curve or surface. Earth based data is a common example of this.

- *How the data is structured* - the simplest case is where the data is sampled on a regular grid. However for experimental reasons, data may only be accessible over a scattered grid, or for computational reasons, unstructured data may be used. In the latter case, the problem may be further complicated by the need to use non-linear interpolation functions.

- *Time-varying* - there could be one or many timesteps - in other words one of the independent variables may be time. This is not necessarily the same as using time to present the result. A time-varying phenomenon could be presented as multiple displays on one frame and sometimes this is preferred if the investigator wishes to make a controlled comparison. A static phenomenon can be presented as a time sequence if there is too much complexity to be presented on one frame - so a volume can be presented as an time-based sequence of slices. Often though - and not surprisingly - time is the preferred way to present a time-varying phenomenon and has been avoided by investigators until now because of technological difficulties. Flow phenomena such as turbulence, eddies and shifting boundaries are perceived without conscious thought when presented using time.

- *Application control* - the simplest case is no control of the application, where data is postprocessed offline of the application. In the other extreme, the investigator needs to exercise full interactive control of the application, in response to events as they are visualized.

- *Size of data set* - many problems become complex, simply through the sheer size of the data set being examined. Effective use of present-day visualization systems often relies on being able to make partly processed copies of the data at various stages. Large data sets make this replication impossible. Vast data sets could be defined as having such a size that they cannot be accomodated at all on the investigator's local processing facilities and have their own special problems.

For convenience, the characteristics are summarised in the following table.

Characteristic	Simple	Hard
Independent variables	1	Multidimensional
Independent variables	1	Multivariate
Data compounding	Scalars	Tensors
Geometry	Cartesian	Curved
Structure	Regular	Unstructured
Time	Static phenomenon	Time-varying
Application control	None - postprocess	Full interactive control steering
	Small	Vast

Table - Characteristics of Investigator's Data

Visualization could be said to encompass problems of all types, whether simple or hard.

In practice many traditional solutions (graphs, bar charts) exist where the characteristics of a problem are simple in all respects or where the problem is hard to a limited degree.

The purpose of much recent work in visualization is to investigate the hard problems and bring them into the realm of the possible. In practice the difficultics are interlinked. So, while it is possible to display a field of scalars in 3D space by some suitable volume rendering techniques, it is much harder if the data are vectors, especially if there are many of them - it is easy to display them but hard to perceive them.

As might be expected, there is a gradual adoption of solutions into commercial systems.

Examples

Some examples may be useful at this point.

- *a simple case* - temperature distribution across a flat surface, a single scalar variable defined in 2D
- *simple 2Dflow problems* - in the simple case, the data exists as a field of veceors at regularly spaced positions in 2D space
- *more complex 3D flow problems* - the data is defined in 3D, an unstructured grid has been used for computational reasons, the flow is time-varying. (these examples are not intended to imply that 2D problems always have a simple structure or that 3D problems are always more complex).
- *Multiple independent variables* - chemical processes are a source of problems, that are hard in most characteristics. The study may involve studying the progress of a chemical reaction at various points in a mixture at various times, depending on several variables, such as pressure, temperature and initial fractions of the constituent substances. In addition flow rates and the use of unstructured data may be involved. In its full complexity, such a problem is still extremely hard to be visualized.

For convenience, these examples are summarised.

Characteristic	Temperature	Simple 2D flow	Complex 3D flow	Chemical process
Independent variables	2	2	3	many
Dependent variables	1	1	1	many
Data compounding	scalar	vector	vector	vector
Geometry	Cartesian	Cartesian	Cartesian	Cartesian
Structure	regular	regular	unstructured	unstructured
Time	static	static	time-varying	time-varying

Table - Examples

Some characteristics have not been presented in the table. For instance the data set size can be small or large in any of the problems just described.

2. Products

In this section, a number of current visualization products are summarised.

Because of the potential complexity of the problems being tackled by visualization, it is important that the investigator have a variety of techniques at hand. Therefore the classification used describes the degree of flexibility (in order of increasing flexibility) allowed to the investigator for composing new visualization techniques.

2.1 Turnkey systems

Turnkey visualization systems provide a fixed set of visualization techniques to the investigator in an efficient way.

The investigator does not have the freedom to alter the techniques provided, but does have the advantages associated with the software coming from one source. Since everything is under their control, the supplier has the opportunity to produce a package which is efficient and responds to the needs of particular applications.

If a particular problem falls within the scope of one of these systems, this can be a good solution. In this section, we present some examples.

The visualization software available on low cost hardware - PC's and Macintoshes - is generally distinct from the software available on workstations, with the occasional rare exeception.

Software available on low cost hardware

- *Cricket Graph* - for problems which can be solved by graphs and bar charts, Cricket Graph is one solution and is available on PC's with DOS or Microsoft Windows 3 and Apple Macintoshes. It is far from being the only solution, but has been selected as the result of a PC graphics evaluation on behalf of the UK academic community, is the subject of a CHEST deal and tutorial workbooks have been produced with the UK academic community in mind.
- *Spyglass* - there are two main visualization programs in the Spyglass suite - Transform and Dicer. Transform can solve problems where the data is defined in 2D on a regular grid. There is a variety of plots for this purpose. It can also handle problems where the data values vary with time. Dicer can handle data, where there is a single scalar at each sample point defined in 3D space. It uses multiple slices to display such data and can also use transparency. Colour is needed to make best use of these programs. Both programs are available on Apple Macintoshes (and also Unix workstations).

There are many packages on PC's which provide technical graphics. An evaluation was carried out in the UK in 1993 and those included in the evaluation were able to handle 3D plots, surfaces and contours - handling scalar data depending on two other variables. Details of the evaluation and a summary of the packages are covered in [AGOCG 22].

Systems available on workstations

- *Uniras* interactive programs - provide a wide range of techniques for 1 or 2 independent variables and for data defined over a surface. Also data defined in 3D space can be displayed using a cut-away blocks method. The Uniras interactives are available as part of a CHEST deal and are available on a wide range of systems including both workstations and mainframes.
- *Data Visualizer* - provides a range of methods for visualizing unstructured vector data defined in 3D and is therefore suitable for a variety of flow problems. The software is available on the more powerful Unix workstations, with 24 bit colour, and does take advantage of 3D capabilities in the workstation hardware where present. Although primarily a turnkey system, the software does allow the investigator to specify special data input formats.
- *Spyglass* - the suite was described earlier. Transform is available on Unix workstations.

Availability in the U.K.:

Spyglass is available from:

> *Aerobel Defence Technology*
> *PO Box 90D*
> *356 West Barnes Lane*
> *Motspur Park*
> *Surrey KT3 6JC*
> *Tel: 081336 1733*
> *Fax: 081 942 8909*

and also from:

> Adept Scientific Micro Systems Ltd
> 6 Business Centre West
> Avenue One

Letchworth
Herts SG6 2HB
Tel: 0462 480055
Fax: 0462 480213

Uniras software is available from

AVS/UNIRAS Ltd
but in the UK academic community,
the CHEST site contact should
be consulted (see the section on CHEST).

Data Visualizer is available from:

Wavefront Technologies Ltd
Oakridge Housc
Wellington Road
High Wycombe
Bucks HP12 3PR
Tel: 0494 441273

2.2 Intermediate Systems

PV-WAVE provides an interactive interface to a wide set of data manipulation and display tools. It provides a command language which has some of the features of a programming language and user procedures can be added. PV-WAVE typically accepts arrays of data which make it suitable for regular data. It can therefore be regarded as intermediate in facilities between the turnkey systems and the data flow systems.

There are additional PV-WAVE products which include: PV-WAVE Point & Click, providing a point and click user interface to the facilities of PV-WAVE; and PV-WAVE Advantage which provides an interface to the IMSL library (since PV-WAVE can also accept user's subroutines, it can also be used with the Nag library).

Availability in the U.K.:

> PV-WAVE products are available from:
> Visual Numerics Ltd
> New Tithe Court
> 23 Datchet Road
> Slough
> SL3 7LL
> tel: 0753 790600
> fax: 0753 790601

In addition, added value software and other services related to PV-WAVE are provided by:

> Tessella Support Services Ltd
> 3 Vineyard Chambers
> Abingdon
> Oxon OX14 3PX
> tel: 0235 555511

fax: 0235 553301
email: postmaster@tessella.co.uk

2.3 Data flow systems - application builders

Data flow systems - or application builders as they are also called - are powerful visualization systems which allow the investigator to control the flow of data through a network of processing modules. In general a number of characteristics are shared by this class of visualization software.

- *Modular approach* - modules can be selected and combined by the investigator for a particular visualization task.

- *Network* - a network of modules may be composed by using a visual interface.
- *Extensible* - a large number of modules are provided by the system and others can be added by the investigator.

The investigator can begin by using already provided visual networks and can then proceed to modify these by selecting other modules from the provided pallette. When experience is gained, modules can be gathered from elsewhere or written oneself and then included in the system.

The result is a powerful capability to proceed by example in easy stages.

The systems summarised here are:

- Application Visualization System (AVS) version 5, from AVS Inc which is now available on most workstation ranges
- Khoros version 1, from University of New Mexico (version 2 will be available soon)
- Visualization Data Explorer (VDE) version 1.2, from IBM Inc (version 2 is becoming available)
- Iris Explorer version 2, from Silicon Graphics Inc (with versions for other workstations being ported by Nag Ltd)

An evaluation of AVS, Khoros and another system apE took place in 1991/92 and is described in a report on behalf of the UK academic community [AGOCG 9]

AVS is the most technically mature of the systems, being now in its release 5 and is available on a wide range of workstations. There is a CHEST deal for AVS.

product	type of access	name
AVS	Email address for automated replies on the current AVS catalogue, on how to obtain modules, the README file on International AVS Center, and on the International AVS User Group Further modules by anonymous ftp NewsGroup	avsemail@ncsc.org ftp.mcc.ac.uk (in U.K.) or avs.ncsc.org comp.graphics.avs
Iris Explorer	Further modules by anonymous ftp To subscribe to mailing list Newsgroup Email address for information on the Iris Explorer gopher service	ftp.epcc.ed.ac.uk explorer-request@castle.ed.ac.uk news:comp.graphics.explorer mailto:caroline@nag.co.uk
Khoros	Newsgroup To subscribe to mailing list	news:comp.soft-sys.khoros khoros-request@chama.eece.unm.edu

Table - online information about Data Flow Systems

2.4 Build Your Own

The investigator may need more flexibility than a data flow system can provide. This can happen if the visualization tasks need to be more tightly coupled with the aMlication. It can also happen if the intemal data fommats are inadequate for the problem in hand.

In such a case, the investigator may decide to construct a purpose built visualization system. The possible ingredients include:

- A development system for uscr interfaces based on X I I toolkits - a report is being produced by RAL about the offerings in this area.
- A graphics system such as PHIGS, PHIGS PLUS or GKS
- Ideally an independent library of advanced visualization techniques would also be available, but this is not the case at present.

It is advisable to carefully consider the facilities that data systems already (or will shortly) provide before committing to the effort required.

3. Other Issues

In this section, a number of important issues are described.

3.1 Performance

Can I do visualization on a PC? The answer is yes and no!

The reader should consult the section on characterising the investigator's problem. Generally, problems towards the simple end of each characteristic can be solved on a PC or Apple Macintosh and suitable products are listed in section 2.1.

If there is a need for interactive viewing of surfaces, for a data flow system, for large data quantities, or for any visualization technique that is at least moderately advanced, any of these would trigger the need for a Unix workstation. In addition a data flow system (other than Khoros which is primarily for images) typically would need a minimum of 16 MBytes of main memory (preferably 24) and an 8-bit colour system. More bits for the colour system would be needed if advantage were being taken of graphics hardware such as Z-buffer, use of techniques which need a large number of colours, such as lighting or transparency; double buffering, which may result from needing animation.

3.2 Video

Video is a suitable medium for studying and presenting the results of visualizing time-varying and other complex phenomena. A visualization user may have access to suitable local video equipment.

If such equipment is not available or if the requirements are more demanding than can be satisfied locally, it may be preferable to use a nationally available facility. The Atlas Video Facility at RAL is introduced in the April 1993 issue of the AGOCG newsletter "Graphics & Visualization" (see under AGOCG below for details). For information on the Atlas Video Facility, contact Chris Osland (cdo@ib.rl.ac.uk). There is also a national video facility in the Computer Graphics Unit, Manchester Computer Centre, University of Manchester. Any interested UK academic user can email for more information to cgu-info@mcc.ac.uk

4. Resources

This booklet is intended as a starter and the reader is likely to need further information. This section provides some possible sources.

4.1 Organisations

UEC SERC Visualization Community Club

The role of the Visualization Community Club is to help researchers, developers and users interested in visualization by:

- providing a forum in which to present and discuss their requirements;
- guiding activities within EASE to meet these reqiJirements;
- increasing awareness through exchange of views and infommation;
- promoting exchange of visualization software and data;
- providing a mechanism for disseminating information to the visualization community through seminars, meetings, workshops and courses.

The Visualization Group at RAL provides visualization support to SERC-supported engineering researchers in the following ways:

- *direct contact* - some researchers need to bc able to put lheir visualization problems in perspective. Is the problem already soluble and if so, how? Is it still an advanced research topic? Is it soluble with some development work? A day or Icss of direct discussion may help with this or altematively we can answer your questions via electronic mail.
- *I to 2 months case study* - a more extended case study base on your visualization problem could be carried out and the results published for the benefit of other researchers.
- *visualization training* - an opportunity to have a hands-on, interactive training session.

The club's Steering Group forms a regular point of contact between the community and EASE technical staff at the Rutherford Appleton Laboratory (RAL). lt is an essential link between the two, representing the views of the larger user community, and transmitting the results of the programme back to the community.

The Chair of the Visualization Community Club is Dr K W Brodlie (University of Leeds) and the Secretary is Ms J Haswell (RAL).

If you wish to join the Community Club, please obtain a registration fomm from:

Mrs M V Jones

Visualization Community Club
Informatics Department
Rutherford Appleton Laboratory
Chilton, Didcot
Oxon OX 11 0QX
fax: 0235 445945
email: mvj@inf.rl.ac.uk

and return it to her.

AGOCG

The Advisory Group on Computer Graphics (AGOCG) is an initiative of the Joint Information Systems Committee of the Higher Education Funding Councils and the Research Councils. It advises UK Higher Education on Computer Graphics, Visualization and Multimedia.

Activities include:

- Software evaluations, for examplc visualization, image processing, presentation graphics;
- Hardware evaluations of peripherals such as scanners and colour printers;
- Awareness exercises, for example training support staff, production of technical reports, Graphical and Visualization Newsletter;
- Addressing support issues by funding people to assist sites in introduction of key technologies, for examplc visualization

AGOCG pays particular attention to visualization by funding a Visualization Support Officer, whose aim is to raise the awareness and promote the use of visualization systems in the UK. To meet these goals, a number of activities and events have been organised. Courses and introductory seminars on AVS arc run by the AGOCG Visualization Support Officer.

The AGOCG Visualization Support Officer manages an online mailing system, which is provided to disseminate general information concerning scientific visualization and its associated software products. In order to subscribe to the online mailing service, send to:

mailbase@mailbase.ac.uk

the following mail message:

join chest-visual your-first-name your-surname

for example:

join chest-visual John Smith

To ask a question, simply send your message to:

chest-visual@mailbase.ac.uk

AGOCG issues every two months a newletter called Graphics & Visualization, with news of graphics and visualization in the UK higher education community. It is intended for all graphics users, developers and support staff in the U.K. (before April 1993, AGOCG's newsletter was called 'Graphics Newsletter'). To submit material to the newsletter, please contact the editor Dr Rae Eamshaw at the University of Leeds (r.a.eamshaw@leeds.ac.uk).

AGOCG Graphics Coordinator:

Dr Anne Mumford
Computing Services
Loughborough University
Loughborough
LE11 3TU
fax: 0509 267477

email: a.m.mumford@lut.ac.uk

Contact for obtaining Graphics & Visualisation newsletter:

Miss Rachel Miles
Informatics Department
Rutherford Appiclon Laboratory
Chilton, Didcot
Oxon OX 11 0QX
email: rym@inf.rl.ac.uk

CHEST

Several packages of software mentioned in this guide arc the subject of deals with suppliers arranged by the Combined Higher Education Software Team (CHEST). CHEST is responsible for negotiating arrangemcnts so that key software becomes widely available throughout a UK university.

CHEST works through a site contact at each institute of higher education, through whom you obtain access to software that is the subject of a CHEST deal. The identity of your local CHEST contact can be found by either contacting your computer centre or by consulting the list of CHEST site contacts on the NISS bulletin board (CALL NISS.BB trom a PAD and consult section D3E). If you have difficully with either of these methods it is possible to contact CHEST directly:

CHEST
fax: 0225 826176
email: chest@bath.ac.uk

ITTI Training Initiative

The ITTI Training Initiative is producing training materials of interest to the computer graphics and visualization community, namely Computer Graphics and Visualization (from University of Manchester) and X and Motif (from University of Edinburgh). Information on all of the projects can be found on the NISS Bulletin Board section H7.

4.2 Events: seminars, workshops and courses - where they are publicised.

Events on visualization (approximately every 3 months) run by the SERC Visualization Community Club are publicised in the SERC Engineering Computing Newsletter. To obtain a copy, contact Miss Rachel Miles at RAL (address is given under the section on AGOCG - see earlier).

Infonmation on general visualization events and sominars including AVS courses for the academic community are posted to the electronic mail list chest-visual (see earlier section on AGOCG for joining instructions).

GraphUK is an electronic mailing list which regularly sends inlonnalion about national and intemational events mnd conferences conceming Computer Graphics and Visualization in general. To subscribe to the list, please send a message to graphuk-requcst@cs.man.ac.uk and any articles should be sent to graphuk@cs.man.ac.uk.

Next: References

5. References

5.1 Books, reports and articles

[Brodlie 92] K.W.Brodlie, L.A.Carpenter, R.A.Eamshaw, J.R.Gallop, R.J.Hubbold, A.M.Mumford, C.D.Osland and P.Quarendon, "Scientific Visualization: Techniques and Applications", Springer-Verlag, 1992

[Earnshaw 92] R.A.Eamshaw, and N.Wiseman, "Introductory Guide to Scientific Visualization" Springer-Verlag, 1992

[Friedhoff 91] R.M.Friedhoff, and W.Benzon, "The Second Computer Revolution Visualization", W.H.Freeman and Co, 1991

[McCommick 87] B.McCormick, T.A.DeFanti, M.D.Brown "Visualisation in Scientific Computing", ACM SIGGRAPH Computer Graphics Vol 21, No 6, Nov 1987

Next: Journals

Next: EASE Visualization Community Club Reports

Next: AGOCG Technical Reports

5.4 AGOCG Technical Reports

[AGOCG 9] "Evaluation of Visualisation Systems", AGOCG Technica1 Report 9

[AGOCG 10] "File Formats for Computer Graphics", L.A.Brankin and A.M.Mumford, AGOCG Technical Report 10

[AGOCG 13] "Review of the PBMPlus Software", P.Herbert, AGOCG Technical Report 13

[AGOCG 14] "Review of the San Diego Image File Conversion Tools", N.Bowers, AGOCG Technical Report 14

[AGOCG 17] "Image Processing Software Evaluation Report", AGOCG Technical Report 17

[AGOCG 22] "Report on PC Technical Graphics Packages", UCSG Graphics Working Party, AGOCG Technical Report 22

These reports can be obtained by contacting:

Ms Joanne Barradell
Computing Scrvices
Loughborough University
Loughhorough
Leics LEI I 3TU
email: barradell@lut.ac.uk